

WE CLAIM:

1. A method of chemical vapor infiltration and deposition, comprising stacking a number of porous structures in a stack, wherein said stack has a center opening region extending through said porous structures and an outer region extending along said porous structures; introducing a first portion of a reactant gas to said center opening region; and introducing a second portion of said reactant gas to said outer region; wherein said first portion and said second portion are controlled proportions thereby introducing predetermined portions of said reactant gas to both said center opening region and said outer region.

2. The method according to Claim 1, wherein said first portion is between about 15% to 80% of said reactant gas and said second portion is between about 85% to 20% of said reactant gas.

3. The method according to Claim 1, wherein said first portion is between about 60% to 80% of said reactant gas and said second portion is between about 40% to 20% of said reactant gas.

4. The method according to Claim 1, wherein said first portion is between about 15% to 35% of said reactant gas and said second portion is between about 85% to 65% of said reactant gas.

5. The method according to Claim 1, further comprising heating said reactant gas to a temperature between about 1,700° F to 1,950° F, depressurizing said reactant gas to a pressure between about 1 torr and 25 torr, and maintaining said temperature and said pressure between about 150 hours to 500 hours.

6. The method according to Claim 1, wherein said reactant gas is a mixture of hydrocarbon gases with between about 80% to 100% natural gas and between about 20% to 0% propane.

7. The method according to Claim 1, further comprising spacing said annular porous structures apart thereby forming open passages therebetween and passing at least some of one of said first and second portions of said reactant gas between said center opening region and said outer region through said open passages.

8. The method according to Claim 1, further comprising blocking at least a portion of said center opening region at one end of said stack, passing at least some of said first portion of said reactant gas out of said center opening region through a hole at said blocked end, and passing at least some of said second portion of said reactant gas out of said outer region without passing to said center opening region.

9. The method according to Claim 1, further comprising spacing one of said annular porous structures at one end of said stack away from a blocking plate thereby forming an open passage therebetween and passing at least some of said first portion of said reactant gas from said center opening region to said outer region through said open passage.

10. The method according to Claim 1, further comprising spacing one of said annular porous structures at one end of said stack away from a blocking plate thereby forming an open passage therebetween and passing at least some of said second portion of said reactant gas from said outer region to said center opening region through said open passage.

11. The method according to Claim 1, further comprising spacing said annular porous structures apart thereby forming open passages therebetween and passing at least some of said first portion of said reactant gas from said center opening region to said outer region through said open passages; and wherein said first portion is between about 60% to 80% of said reactant gas and said second portion is between about 40% to 20% of said reactant gas.

12. The method according to Claim 11, further comprising spacing one of said annular porous structures at one end of said stack away from a blocking plate thereby forming an open passage therebetween and passing at least some of said first portion of said reactant gas from said center opening region to said outer region through said open passage.

13. The method according to Claim 12, further comprising blocking at least a portion of said center opening region at one end of said stack, passing at least some of said first portion of said reactant gas out of said center opening region through a hole at said blocked end, and passing at least some of said first portion commingled with said second portion out of said outer region away from said center opening region blocked end.

14. The method according to Claim 13, further comprising heating said reactant gas to a temperature between about 1,700° F to 1,950° F, depressurizing said reactant gas to a pressure between about 1 torr and 25 torr, and maintaining said temperature and said pressure between about 150 hours to 500 hours; and wherein said reactant gas is a mixture of hydrocarbon gases with between about 80% to 100% natural gas and between about 20% to 0% propane.

15. The method according to Claim 1, further comprising spacing said annular porous structures apart thereby forming open passages therebetween and passing at least some of said second portion of said reactant gas from said outer region to said center opening region through said open passages; and wherein said first portion is between about 15% to 35% of said reactant gas and said second portion is between about 85% to 65% of said reactant gas.

16. The method according to Claim 15, further comprising spacing one of said annular porous structures at one end of said stack away from a blocking plate thereby forming an open passage therebetween, passing a remaining portion of said second portion of said reactant gas from said outer

region to said center opening region through said open passage, blocking said outer region at one end of said stack, and passing said first portion and said second portion commingled out of said center opening region through an exit hole in said blocking plate.

5 17. The method according to Claim 15, further comprising spacing one of said annular porous structures at one end of said stack away from a blocking plate thereby forming an open passage therebetween, passing most of a remaining portion of said second portion of said reactant gas from said outer region to said center opening region through said open passage,
10 blocking said outer region at one end of said stack, passing said first portion and most of said second portion commingled out of said center opening region through an exit hole in said blocking plate, and passing at least some of said second portion out of said outer region through holes in said blocking plate away from said exit hole.

15 18. The method according to Claim 1, in combination with a prior densification process, wherein the prior densification process comprises passing a reactant gas between a prior center opening region and a prior outer region, and wherein the method further comprises passing most of one of said first and second portions of said reactant gas between said center
20 opening region and said outer region in an opposite direction to that of the prior densification process.

 19. The method according to Claim 18, wherein both the prior densification process and the method further comprise spacing said annular porous structures apart thereby forming open passages therebetween
25 whereby said reactant gas passes between said prior center opening region and said prior outer region through said open passages and said reactant gas passes between said center opening region and said outer region through said open passages.

20. The method according to Claim 18, wherein the prior densification process further comprises sealing open passages between adjacent annular porous structures thereby constricting flow between said prior center opening region and said prior outer region and thereby forcing said reactant gas to flow through an interior region of said porous structures, and wherein the method further comprises spacing said annular porous structures apart thereby forming open passages therebetween whereby said reactant gas passes between said center opening region and said outer region through said open passages.

21. The method according to Claim 20, wherein the prior densification process further comprises forcing most of said reactant gas from said prior center opening region to said prior outer region, and wherein the method further comprises passing most of said reactant gas from said outer region to said center opening region.

22. The method according to Claim 21, wherein said first portion is between about 15% to 35% of said reactant gas and said second portion is between about 85% to 65% of said reactant gas.

23. The method according to Claim 21, wherein the prior densification process further comprises forcing substantially all of said reactant gas from said prior center opening region to said prior outer region, and wherein the method further comprises passing substantially all of said reactant gas from said outer region to said center opening region.

24. A furnace for densifying a number of porous structures stacked adjacent each other in a stack, wherein the stack comprises a center opening region and an outer region, the furnace comprising an inlet duct and an outlet duct; and an inlet opening adjacent one end of said center opening region and in communication therewith, a size of said inlet opening controlling gas flow to said center opening region wherein a predetermined first portion of said gas

passes through said inlet opening to said center opening region and a remaining second portion passes to said outer region.

5 25. The furnace according to Claim 24, further comprising a hole receiving said gas from said inlet duct and a passageway extending from said hole to said outer region, said second portion passing through said passageway to said outer region.

10 26. The furnace according to Claim 25, further comprising a distributor, wherein said hole and said passageway extend through said distributor, said passageway being a radial hole and said hole being in communication with said inlet opening, wherein said distributor is disposed between a floor plate of the furnace and a base plate supporting the stack, and wherein said radial hole passes said second portion to a space between said floor plate and said base plate.

15 27. The furnace according to Claim 25, further comprising a base plate supporting the stack, wherein said inlet opening extends through said base plate, said inlet opening comprising said hole and a smaller, upper hole wherein said hole is a larger, lower hole, wherein said passageway extends through said base plate to an outer edge of said base plate.

20 28. The furnace according to Claim 24, further comprising a spacer disposed between a floor plate of the furnace and a base plate supporting the stack thereby forming an open space therebetween, said open space receiving said gas from said inlet duct, wherein said inlet opening extends through said base plate thereby being in communication with said open space, and wherein said open space is in communication with said outer region.

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 29. The furnace according to Claim 24, wherein said first portion is between about 60% to 80% of said gas and said second portion is between about 40% to 20% of said gas.

30. The furnace according to Claim 24, wherein said first portion is between about 15% to 35% of said gas and said second portion is between about 85% to 65% of said gas.

5 31. The furnace according to Claim 24, further comprising spacers disposed between adjacent porous structures in the stack thereby forming open passages therebetween, wherein some of one of said first and second portions of said gas passes between said center opening region and said outer region through said open passages.

10 32. The furnace according to Claim 24, further comprising a plate disposed away from one of the porous structures at one end of the stack thereby blocking a portion of said first portion of gas from passing out of said center opening region at said end and thereby forming an open passage therebetween wherein some of said gas passes between said center opening region and said outer region through said open passage.

15 33. The furnace according to Claim 24, further comprising a plate disposed at one end of the stack of porous structures thereby blocking most of said first portion of gas from passing out of said center opening region at said end, said plate comprising at least one hole adjacent said center opening region and extending therethrough, wherein at least some of said gas passes
20 out of said center opening region at said end through said hole.

25 34. The furnace according to Claim 24, further comprising a cap disposed at one end of the stack of porous structures and extending partially into said center opening region thereby blocking most of said first portion of gas from passing out of said center opening region at said end, said cap comprising at least one longitudinal hole, wherein at least some of said gas passes out of said center opening region at said end through said longitudinal hole.

35. The furnace according to Claim 34, further comprising a thermocouple wire installed through said longitudinal hole and extending

through said center opening region, said thermocouple wire being connected to a thermocouple embedded in a sample porous structure.

5 36. The furnace according to Claim 24, further comprising a plate disposed at one end of the stack, wherein said plate comprises an exit hole adjacent said center opening region, said plate blocking said outer region whereby substantially all of said second portion of gas passes through one or more of said exit holes.

10 37. The furnace according to Claim 24, further comprising a plate disposed at one end of the stack, wherein said plate comprises an exit hole adjacent said center opening region and a smaller hole away from said exit hole, said plate blocking said outer region whereby most of said second portion of gas passes through one or more of said exit holes and at least some of said second portion passes through one or more of said smaller holes.

15 38. The furnace according to Claim 24, further comprising a hole receiving said gas from said inlet duct and a passageway extending from said hole to said outer region, said second portion passing through said passageway to said outer region; and a distributor, wherein said hole and said passageway extend through said distributor, said hole being in
20 communication with said inlet opening, wherein said distributor is disposed between a floor plate of the furnace and a base plate supporting the stack, and wherein said passageway passes said second portion to a space between said floor plate and said base plate; wherein said first portion is between about 60% to 80% of said gas and said second portion is between
25 about 40% to 20% of said gas; and further comprising spacers disposed between adjacent porous structures in the stack thereby forming open passages therebetween, wherein some of said gas passes from said center opening region to said outer region through said open passages.

39. The furnace according to Claim 38, further comprising a plate disposed away from one of the porous structures at one end of the stack thereby blocking a portion of said first portion of gas from passing out of said center opening region at said end and thereby forming an open passage therebetween wherein some of said first portion of gas passes from said center opening region to said outer region through said open passage.

40. The furnace according to Claim 39, further comprising a cap disposed at one end of the stack of porous structures and extending partially into said center opening region thereby blocking most of said first portion of gas from passing out of said center opening region at said end, said cap comprising at least one longitudinal hole, wherein at least some of said gas passes out of said center opening region at said end through said longitudinal hole; and a thermocouple wire installed through said longitudinal hole and extending through said center opening region, said thermocouple wire being connected to a thermocouple embedded in a sample porous structure.

41. The furnace according to Claim 24, further comprising a hole receiving said gas from said inlet duct and a passageway extending from said hole to said outer region, said second portion passing through said passageway to said outer region; and a base plate supporting the stack, wherein said inlet opening extends through said base plate, said inlet opening comprising said hole and a smaller, upper hole wherein said hole is a larger, lower hole, wherein said passageway extends through said base plate to an outer edge of said base plate; wherein said first portion is between about 60% to 80% of said gas and said second portion is between about 40% to 20% of said gas; and further comprising spacers disposed between adjacent porous structures in the stack thereby forming open passages therebetween, wherein some of said first portion of gas passes from said center opening region to said outer region through said open passages.

42. The furnace according to Claim 41, further comprising a plate disposed away from one of the porous structures at one end of the stack

thereby blocking most of said first portion of gas from passing out of said center opening region at said end and thereby forming an open passage therebetween wherein some of said gas passes from said center opening region to said outer region through said open passage; said plate comprising
5 at least one hole adjacent said center opening region and extending therethrough, wherein at least some of said gas passes out of said center opening region at said end through said hole.

43. The furnace according to Claim 24, further comprising a spacer disposed between a floor plate of the furnace and a base plate supporting the
10 stack thereby forming an open space therebetween, said open space receiving said gas from said inlet duct, wherein said inlet opening extends through said base plate thereby being in communication with said open space, and wherein said open space is in communication with said outer region; wherein said first portion is between about 15% to 35% of said gas
15 and said second portion is between about 85% to 65% of said gas; and further comprising spacers disposed between adjacent porous structures in the stack thereby forming open passages therebetween, wherein some of said second portion of gas passes from said outer region to said center opening region through said open passages.

44. The furnace according to Claim 43, further comprising a plate disposed at one end of the stack, wherein said plate comprises an exit hole adjacent said center opening region, said plate blocking said outer region
20 whereby substantially all of said second portion of gas passes through one or more of said exit holes; wherein said plate is disposed away from one of the porous structures at said end of the stack thereby forming an open passage
25 therebetween wherein some of said second portion of gas passes from said outer region to said center opening region through said open passage.

45. The furnace according to Claim 43, further comprising a plate disposed at one end of the stack, wherein said plate comprises an exit hole
30 adjacent said center opening region and a smaller hole away from said exit

hole, said plate blocking said outer region whereby most of said second portion of gas passes through one or more of said exit holes and at least some of said second portion passes through one or more of said smaller holes; wherein said plate is disposed away from one of the porous structures at said end of the stack thereby forming an open passage therebetween wherein some of said second portion of gas passes from said outer region to said center opening region through said open passage.

46. A composite structure having a first region and a second region manufactured by a process comprising heating a reactant gas; dividing said reactant gas into a predetermined first portion and a predetermined second portion; introducing said first portion of reactant gas to said first region of the composite structure; and introducing said second portion of reactant gas to said second region of the composite structure.

47. The composite structure according to Claim 46, wherein said first portion is between about 60% and 85% of said reactant gas and said second portion is between about 40% and 15% of said reactant gas.

48. The composite structure according to Claim 47, wherein said reactant gas is a hydrocarbon gas.

49. The composite structure according to Claim 48, further comprising stacking a plurality of the composite structures on top of each other and installing spacers between adjacent composite structures, thereby creating open passages between the adjacent composite structures, said open passages connecting said first region and said second region together.

50. The composite structure according to Claim 49, wherein the composite structure is an annular structure, said first region being a center opening region and said second region being an outer region.

51. The composite structure according to Claim 49, wherein the composite structure is an annular structure, said first region being an outer region and said second region being a center opening region.

5 52. A method of densifying a composite structure having a first region and a second region with chemical vapor infiltration and deposition processes, comprising a first densification process and a second densification process, wherein said first densification process comprises passing a reactant gas between said first region and said second region, and wherein said
10 second densification process comprises passing most of said reactant gas in an opposite direction to that of said first densification process.

53. The method according to Claim 52, wherein both the first and second densification processes further comprise spacing the composite structures apart thereby forming open passages therebetween whereby said reactant gas passes between said first region and said second region through
15 said open passages.

54. The method according to Claim 52, wherein the first densification process further comprises sealing open passages between the composite structures thereby constricting flow between said first region and said second region and thereby forcing said reactant gas to flow
20 through an interior region of the composite structures, and wherein the second densification process further comprises spacing the composite structures apart thereby forming open passages therebetween whereby said reactant gas passes between said first region and said second region through said open passages.

25 55. The method according to Claim 54, wherein the prior densification process further comprises forcing substantially all of said reactant gas from said first region to said second region, and wherein said second densification process further comprises passing most of said reactant gas from said second region to said first region.

56. The method according to Claim 54, wherein the prior densification process further comprises forcing substantially all of said reactant gas from said first region to said second region, and wherein said second densification process further comprises passing substantially all of said reactant gas from said second region to said first region.
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